

Smart Kitchens for People with Cognitive Impairments: A Qualitative Study of Design Requirements

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ABSTRACT

Individuals with cognitive impairments currently leverage extensive human resources during their transitions from assisted living to independent living. In Western Europe, many government-supported volunteer organizations provide *sheltered living facilities*; supervised environments in which people with cognitive impairments collaboratively learn daily living skills. In this paper, we describe communal cooking practices in sheltered living facilities and identify opportunities for supporting these with interactive technology to reduce volunteer workload. We conducted two contextual observations of twelve people with cognitive impairments cooking in sheltered living facilities and supplemented this data through interviews with four employees and volunteers who supervise them. Through thematic analysis, we identified four themes to inform design requirements for communal cooking activities: Work organization, community, supervision, and practicalities. Based on these, we present five design implications for assistive systems in kitchens for people with cognitive deficiencies.

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People with Cognitive Impairments; Assistive Systems; Smart Kitchens; Sheltered Housing; Accessibility

INTRODUCTION

Today, approximately 20% of the world's population lives with some level of cognitive impairment [36]. An individual with a cognitive impairment may have difficulties in learning, remembering information, or making decisions as the result of a genetic condition, injury, or aging-related diseases. A cognitive impairment can impact someone's ability to complete traditional activities of daily living, such as cooking or

bathing [37]. Numerous government and volunteer-driven organizations exist to provide specialized training to people with cognitive impairments as they learn these independent living skills. As average lifespans increase, the number of people affected temporarily or permanently by cognitive impairment will continue to rise [18], and this training will be in higher demand.

In continental Europe, one venue for learning independent living skills are sheltered living facilities, which are housing communities where tenants with cognitive impairments live together with supervision from at least one caretaker. In these facilities, 20 to 30 people share living quarters and are coordinated in learning daily living skills by expert staff members and teams of volunteers. The ultimate goal of a sheltered living facility is to teach the inhabitants to live independently with other cognitively impaired tenants who help and support each other. The organization supports tenants in moving to a shared flat, where four to six people help each other without any caretaker supervision. Consequently, the facilities provide training in both the acquisition of life skills and the social organization of a community of cognitively impaired tenants.

Communal cooking is one activity that integrates both of these aspects of living in sheltered housing facilities. Tenants learn to complete their individual kitchen duties to benefit other members of the community. In sheltered housing, instructors provide the group with specialized supervision on safe cooking methods and techniques for cooking collaboratively. However, due to worker shortages in this field, individual instruction is rarely possible. Further, some assistance in cooking may still be needed by the cognitively impaired tenants who have transitioned to independent living facilities.

Contextualized assistance (delivered through displays [23] or augmented reality [22]) has been shown to be effective in helping people with cognitive impairments perform individual work. While the workload from caretakers may be alleviated when using digital assistance in communal cooking activities, support and learning can be provided independently from the sheltered living facility. In this paper, we describe current training practices in sheltered living facilities, and explore potential challenges and benefits of providing *communal* contextual instruction and support for the development independent living skills. Using contextual observation of communal cooking sessions in sheltered living facilities and supplementary interviews with staff members and volunteers, we chart the op-

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opportunities, tradeoffs, and constraints involved in designing for communal kitchens for the cognitively impaired. Our contribution is threefold: (1) we report a qualitative study of current communal cooking practices in sheltered establishments, (2) describe four themes regarding the design opportunities and constraints in communal kitchen for cognitively impaired, and (3) conclude with five implications for assistive technologies supporting cooking in sheltered housing.

This paper is organized as follows: First, we review past efforts in designing for the cognitively impaired and show how they inspired our work. Next, we provide details of our qualitative inquiry. We then report on four themes we identified in our data: WORK ORGANIZATION, COMMUNITY, SUPERVISION, and PRACTICALITIES. Finally, we present five design implications derived from the themes.

RELATED WORK

Previous research has investigated efforts in supporting cognitively impaired people during everyday tasks. In the following, we provide an overview of related work aiming to assist persons with cognitive deficiencies. We provide (1) an overview of technologies supporting cognitively impaired during everyday tasks. This is complemented by (2) current research, which aims to provide contextual assistance in kitchens.

Accessibility Through Assistive Systems

Various researchers have invested the effort to explore and design assistive systems for impaired people. Bouchard et al. [5] developed a plan recognition framework in smart homes for people suffering from dementia. Using microsensors, the framework analyses previous actions to predict the original intention of the person. Pollack et al. [38] define goals for assistive technologies when used by older people with cognitive impairments. Furthermore, three different types of assistive systems are defined: assurance, compensation, and assessment systems. Since smart environments need to be equipped with microsensors to measure contextual parameters of their surroundings [32], ethical implications for assistance systems in home environments were to be defined [42]. Assistive technologies provide a number of benefits, such as workload reduction, socialization, or care delivery. However, the use of such technology has ethical ramifications and considerations. To enable independent living for the people with cognitive impairments, a smart home system leveraging several sensors, such as infrared motion sensors, microphone arrays, and accelerometers, was used to sense contextual data [1]. The collected data was used to train an artificial intelligence, which provides adaptive assistance whenever required. However, challenges such as preserving privacy [14, 15] and acceptance by senior users [8, 17] have to be considered. Mihailidis et al. [33] presents an assistive system supporting older adults with dementia during regular daily activities.

Within workplaces in industrial areas, augmented reality was used to provide cognitive alleviation for cognitively impaired workers in workplaces [11] and assembly lines [22]. They found that by projecting in-situ information about the current assembly step, increased efficiency with respect to time and

number of errors would be achieved, and concluded that assistive systems at workplaces foster learning by skill transfer while releasing cognitive resources at the same time [23, 24]. Gamification can be incorporated into assistive systems to maintain or increase motivation [27, 28, 29].

Research has also concerned notifying persons about events, such as warning of dangers or sending reminders. Kosch et al. [30, 31] investigated how events of interest can be communicated efficiently with cognitively impaired persons within workplaces. By comparing visual, auditory, and tactile feedback, their findings show that visual in-situ cues are perceived efficiently. A survey exploring how notifications in smart homes can be communicated was carried out by Voit et al. [45]. Leveraging an online survey, they investigated suitable devices and locations displaying notifications. Their results showed that smart home-related notifications should be received by mobile devices which would be easily perceivable when worn on the body. Wiehr et al. [46] define how the increasing number of notifications raise challenges regarding design, implementation, and psychological factors of users.

Assistive Technologies in Kitchens

Smart kitchens have been the focus of Blasco et al. [3]. They developed and assessed smart kitchens for older adults and evaluated the simulation of specific situations, such as making dinner or washing up. Besides providing assistance in kitchens, calorie and nutrition-aware contextual cooking plans can be provided [12, 13]. By displaying information about nutrition during cooking, healthier ingredients can be chosen by cooks. Hashimoto et al. [25] designed algorithms for smart kitchens, which recognize the users' cooking actions and food material. Since recipes play an important role in cooking, Schneider et al. [40] developed a semantic cookbook. The semantic cookbook is a system enabling different parties to share their recipes among their smart kitchens to display it on an output device. As most handwritten recipes are passed down by previous generations, digital recordings can ensure the continued existence of recipes and can be easily shared. Cooking can also represent a method for social communication and interaction. Therefore, Terrenghi et al. [43] present the "Living Cookbook". In their work, cooking experiences are recorded to educate others, practice cooking techniques, or share cooking experiences. An evaluation of the "Living Cookbook" shows that its use increased motivation and improved social communication. Hooper et al. [26] investigates how the new material can be learned within instrumentalized environments to support task-based learning. During the course of their research, the efficiency and design space of learning new languages within regular cooking tasks were evaluated. Bonanni et al. [4] evaluate several augmented kitchen interfaces regarding their usability. Their studies focus on usability as well as interfaces which are not demanding in terms of attention and cognitive workload. Miyawaki et al. [34] prototyped a kitchen for people with higher brain dysfunction. Olivier et al. [35] presents a lab-based replication of a smart kitchen, where designers can evaluate novel solutions. In addition, Scheible et al. [39] show how social and emotional components can be incorporated in the cooking process.

Overall, previous work has investigated effort into the development, design, and evaluation of assistive systems. However, the design space of smart kitchens for cognitively impaired people has not been considered yet in related research. Through the execution of qualitative contextual inquiries with caretakers and observations of tenants in sheltered living organizations for people with cognitive disabilities, we close this gap by charting the design space for smart kitchens for cognitively impaired users.

Collaborative Accessibility

People with disabilities often *co-construct accessibility* in spaces alongside the other disabled or able-bodied peers who inhabit them [6]. This process of co-construction involves a large amount of collaboration among individuals as they stage environments to be more accessible; divide tasks and responsibilities based on ability, and intervene or request assistance for tasks that are not accessible.

Branham and Kane [6] described the collaborative accessibility practices of blind and sighted domestic partners in their home settings. Within these close partnerships, partners can set up plans for managing household tasks, object placement, and requests for assistance. However, this collaboration to make accessible environments can be less successful in work settings, where an intimate understanding of the disability is not possessed by a disabled person's co-workers [7]; or in public spaces where accessibility cannot be co-constructed in advance [47].

The study of this collaboration work has been rare among people with cognitive impairments. In our observations in this study, we examined the collaboration between individual cognitively impaired tenants and the neurotypical¹ instructors who supervised them; however, we also discuss opportunities for collaboration between multiple cognitively impaired tenants without supervision.

METHODS

Sheltered living facilities offer people with cognitive impairments assistance with learning everyday tasks, including cooking. The main goal is to teach elementary skills in a methodical way that can be reapplied in independent living environments. When tenants make progress in applying their skills without caretaker intervention in the facility, they can move to live more independently in houses shared with a small number of other people with cognitive impairments. The research for this paper was conducted in collaboration with a sheltered living organization in Germany which operates both a sheltered living facility and independent houses for tenants who have completed their training.

Context: Communal Kitchens

The kitchen in the sheltered living facility and independent living homes use regular components necessary to cook a meal,

¹We use the term 'neurotypical' here to describe individuals without any measurable level of cognitive impairment. This term is often used to differentiate people with a neurological disorder, like individuals on the Autism spectrum or with cognitive impairments, from individuals without a neurological disorder.



Figure 1. A kitchen in a sheltered living facility, used by the tenants with cognitive impairments and the caretakers.

such as an oven, stove, tabletop, and refrigerator. The kitchen from the sheltered living facility is shown in Figure 1.

Within the sheltered housing, tenants and caretakers cook dinner every weekday evening. If enough inhabitants stay at the sheltered housing during weekends, both lunch and dinner are cooked. The way supervision is provided depends on whether the inhabitants are living in sheltered facilities or residing in their own independent homes.

Major supervision during cooking is mostly provided by a caretaker within the sheltered housing. A sheltered living facility comprises 20 to 30 inhabitants depending on its size. Groups of four to six inhabitants cook together with at least two caretakers who explain the course of cooking in the beginning, distribute tasks, and make sure that the participants avoid serious injuries. Currently, no standardized assistive technology supporting caretakers is enrolled in such facilities. Dangerous tasks, such as operating the oven, are only performed by caretakers.

Minor supervision is necessary for cognitively impaired persons living in independent housing. This independent place is managed by the sheltered living organization but spatially separated from the sheltered living facility. Such independent living places comprise between four and six inhabitants living together. This principle enables maintaining social settings where people can help each other. For cooking, the same rules apply for the sheltered housing. However, only a single caretaker is present to avoid possible injuries and provide advice on demand. The caretaker also assesses the social setting, cognitive development, and skill progress of the inhabitants.

Data Collection

Data for this paper was collected through two observation sessions of communal cooking in a sheltered living facility and an independent living facility in Germany and was supplemented by semi-structured interviews with staff members from those

organizations. The tenants who participated in the cooking sessions ranged between 30 and 49 years old. Ethical approval for all components of the study was given by the sheltered living organization and the German Federal Ministry of Education and Research according to institutional guidelines.

We chose to conduct observations rather than interspersing interview questions throughout the task as in a contextual inquiry, due to the level of cognitive impairment among our participants and the time-based nature of the cooking tasks being taught. Cognitive impairment impacts executive functioning, like task planning and memory. Interruptions during a time-based task make it more difficult for a person with a cognitive impairment to hold onto their original intention, and less likely to return to the task after being distracted [44]. At the direction of the caretakers at the facility, we limited interaction with the cognitively impaired tenants during the cooking tasks and used follow-up interviews with staff members to supplement our understanding of the observed data. The contextual inquiry was thus carried out with the caretakers, which have been observed and interviewed during the course of this study [2]

Observations

We conducted two observations in communal kitchens as tenants prepared meals. We observed communal cooking processes among four to eight participants - the number of tenants in the kitchen at one time varied as they arrived and left the kitchen at their own discretion, but a total of twelve participants were observed between the two sessions. Two rounds of observation were performed — one of a *supervised cooking session* in the sheltered living facility, and one of a *unsupervised cooking session* in an independent household managed by the same organization. Each observation session lasted at least one hour. A caretaker was present in each kitchen at all times during our observations but did not intervene in the cooking activities in the unsupervised session.

In the supervised cooking session, ten participants we observed were born with a cognitive impairment limiting their ability to understand and process information. In addition to this, two other participants were affected by light motoric impairments. All participants we observed in the unsupervised cooking session were affected by a cognitive impairment limiting their ability to understand and process information. None of the participants were affected by sensory impairments or dementia.

Our observations were documented through notes and photographs. We took pictures of the cooking environments before the tenants began cooking to limit task disruptions. During the observation, two researchers took detailed field notes on the session. Observations focused on how the cooking process was organized and the interactions between the tenants. In the observation of the structured cooking session, we also observed how the caretakers provided instruction to the tenants and how they directed their attention. We noted how physical artifacts in the kitchens were used, arranged and assigned by the tenants. In each of the two observations, we remained in the kitchen for the entire duration of the cooking process, from before the tenants started arriving in the kitchen to when

they left the room after having eaten. We have not interacted with the tenants directly as we wanted to avert confusions and avoid disruptions during the regular cooking procedure.

Interviews

After the observations, we constructed specific semi-structured interview protocols for the caretakers to clarify and refine our understanding of the data collected during the cooking sessions. The primary focus of these interviews was to better understand the work processes and roles assigned involved in the structured cooking sessions, such as the reasons for distributing particular tasks, rules for using appliances, and methods for distributing the workload among tenants. We were also able to inquire further about the role of cooking in the community of cognitively impaired tenants in both structured and unstructured settings.

Participant	Role	Age	Experience
P1	Housing officer	33	15 years
P2	Sheltered caretaker	49	30 years
P3	Sheltered caretaker	20	0.5 years
P4	Independent caretaker	46	6 years

Table 1. Demographic data and working experience of the interviewed participants.

The interviews comprised one interview with the housing officer of a sheltered living institution (a person whose full-time job is to manage the facilities), two interviews with volunteer caretakers working at a sheltered housing facility, and one caretaker responsible for an independent group of persons living together. Overall, 5:45 hours of recordings were collected. The mean age ranged from 20 to 49 years ($M = 37$, $SD = 13.29$) and working experience of caretakers ranged from six months to 30 years ($M = 12.88$, $SD = 12.87$). P1, who is a housing officer and responsible for multiple living facilities, provided us with most data about the observed cooking processes as well as general information. The interviews from P2, P3, and P4 were largely used to gain new insights and to confirm the statements provided by the housing officer.

Data Analysis

We conducted a qualitative analysis of our observation notes and interview transcripts to understand the constraints and opportunities of communal cooking experiences for cognitively impaired users. We used a team consisting of two coders working with the Atlas.ti software package. We conducted initial open coding of 25% of the data by both researchers. Afterwards, a coding tree was established through iterative meetings. We then coded the rest of the data with the agreed-upon set of codes. A final meeting was conducted where we grouped codes to establish the four emergent themes: WORK ORGANIZATION, COMMUNITY, SUPERVISION, and PRACTICITIES.

FINDINGS

In this section, we present four themes that emerged from the analysis of our dataset. We present each theme and our understanding of the constraints, tradeoffs, and opportunities involved.

Work Organization

Cooking was seen as a key activity in the learning process required for gaining a higher degree of independence. In our observations, both tenants and supervisors gave heavy attention and concern to how tasks were divided within the cooking group. Much of this task division within the supervised cooking session was done by the supervisors in advance, and tasks were created both for the tenants cooking that day and for the supervisor on duty. The supervisors communicated clearly which tasks were intended to be performed by tenants and which were reserved for supervisors:

*"Tasks are usually divided between tenants and supervisors. The parts were carried out until completed; nobody stops suddenly within their task."*² (P1)

One supervisor showed us how a weekly cooking plan helped organize the communal activities in the group. The cooking duties were distributed every week within a weekly meeting where supervisors and tenants took part. The cooking responsibilities were discussed verbally. Tenants were informed about their responsibilities by the assigned supervisors.

These plans served as a valuable organization and accountability tools on tenants' journey to greater domestic independence. One officer explained that managing schedules and making sure all tenants were involved in cooking served not only practical purposes but also worked as a means of assuring participation in this important activity of daily living on days when tenants were not intrinsically motivated:

"Many tenants do not feel like they want to cook... A cooking plan is created, which forces everyone to cook regularly. Usually, we find out whether there are any important appointments before a cooking schedule is created." (P1)

The supervisors assumed responsibility for developing these plans, leveraging their knowledge of tenants' current ability levels and other commitments to make the plans maximally effective in the limited time available.

Coordination in the kitchen was necessary, as the kitchens constituted the only common rooms in the facilities we visited. We observed tenants constantly entering and exiting the kitchens. Some tenants who were not involved in cooking tasks that day came to socialize or observe the cooking tenants. Other tenants who were assigned to specific cooking duties might leave their task briefly, and return to them after a short walk. The diverse patterns of the tenants within the kitchen at any time meant that supervisors had to engage in constant monitoring of task completion to ensure that coordination was occurring.

The division of labor among stakeholders was emphasized not only in terms of which tenants performed which kitchen duties, but also with respect to assigning paid personnel and volunteers to supervision:

"There is a duty roster for interns and employees. This plan specifies, how many supervisors have to be there during cooking." (P2)

External factors also affected the way kitchen work was organized. For example, drinks provided by an external supplier arrived on a fixed schedule that also needed to be included in the kitchen plans:

"Drinks are delivered every week on Wednesday. The group buys groceries by themselves every Tuesday and Friday. On Wednesday, we buy groceries together. Usually, one supervisor is associated with each tenant." (P1)

These considerations show the considerable amount of coordination that is required for the supervisors and tenants in the supervised cooking environments. While the meta-level scheduling work was performed solely by the supervisors, individual cooking sessions and supportive tasks were more collaborative efforts between volunteers and tenants.

Overall, we observed the multiple aspects of the division of labor, time management, and logistics, all of which significantly affected the way the cooking was enacted.

Community

The social dynamics of the sheltered living community were important to both tenants and to the supervisors, who saw these social relationships as valuable learning experiences. Aspects of communication and collaboration between tenants and supervisors were often observed and mentioned in our data set. Tenants interacted with each other while cooking and the supervisors reported that due to social expectations, tenants did not eat alone and instead joined communal activities:

"Nobody would cook together and then decide to eat alone in his room." (P1)

Tenants who were not assigned cooking tasks enjoyed observing the cooking tenants performing their duties and would choose to join the kitchen and monitor the cooks as they worked through their tasks.

While the cognitively impaired tenants did not initiate social activities outside of the facility, the supervisors often planned these events as an important training experience for gaining independence:

"We go to the cinema or do other activities on weekends. But this depends on the initiative of the supervisors." (P1)

These independence-building activities helped to foster community among the tenants and supervisors, and could be useful in preparing tenants to navigate social relationships in the more independent housing options.

Despite this emergent community among the tenants and supervisors, there was potential for conflicts to occur connected with the execution of the kitchen work. Supervisors, in particular, were concerned about these potential conflicts and helping the tenants resolve these conflicts amicably. One supervisor reflected on how some tenants were particularly concerned about the alignment of cutlery on the kitchen table, indicating

²Quotes presented in this paper have been transcribed from their original German into English.

that tenants with different levels of ability might experience frustration with each other:

"How exactly cutlery is placed depends on the individual person. Some execute their tasks very accurately, while others do their tasks in a rudimentary way. We often experience conflicts between inhabitants because of that." (P1)

Similarly, another supervisor was concerned about how critique could be communicated gently, and how it affected tenants differently:

"Some have problems accepting critique and answer with statements like 'This has been always been done this way.' (P2)

These interpersonal disagreements are likely to arise in more independent kitchens as well, so supervisors desired more effective ways to resolve these conflicts.

Within the community of tenants, different tenants assumed unique roles in the cooking process. This often was at odds with the goals of the supervisors, who wanted tenants to participate in cooking equally as part of their rehabilitation. Instead, more motivated tenants often tried to monopolize the cooking positions:

"Our tenants are very motivated to shop for the ingredients. However, the motivation regarding cooking is different per person. Surprisingly, it is always the same persons who volunteer for kitchen service." (P3)

Some tenants were not intrinsically motivated to do the complex work required in the kitchen. In these instances, social factors were often mentioned by supervisors as key to increasing their motivation. Enabling tenants to express approval of each other's actions and their role in the community was seen as extremely valuable to the group dynamics:

"Approval of other tenants is important; much more important than approval from the supervisors." (P2)

Supervision

The nature of the supervision provided to the tenants was a unique aspect of work in a sheltered housing facility. Supervisors explained that maintaining engagement and limiting frustration for tenants was one of the most important purposes of their work and one of the primary goals of the more structured cooking sessions. They conducted this supervision work both pre-emptively (while doing WORK ORGANIZATION, as described above) and by being available to help or intervene during the tasks themselves:

"We sort from the beginning inhabitants for specific tasks; for example if it is clear that a particular person should not cut hard things instead of vegetables and salad. They call for help if something is too difficult for them. We have to avoid frustration and confusion if inhabitants are not able to do their task." (P1)

Tenants were able to request help if needed, and the amount of supervision needed varied from tenant to tenant. In general, there was a high emphasis on tenant independence, and the

details in the instructions provided to the tenants were left sparse to allow them to develop skills on their own. In their role as supervisors, staff was most concerned that a given individual would be able to generally complete kitchen actions and that they pay attention to learning precise techniques to a sufficient degree:

"Most people can cut. We do not complain if something is cut too thick or thin. The most important thing is that it is cut and can be cooked." (P1)

Guidance from supervisors was primarily required when tenants made mistakes or grew confused. When this occurred, both supervisors and other tenants stepped into a supervisory role to help the tenants understand the issues with their work. Feedback from all members of the group was often provided. Tenants who intervened were often concerned about the process implications of an error (e.g., if a mistake would impact the overall meal) or highlighted safety concerns when they noticed unsafe behavior. For supervisors, helping the tenant understand what went wrong in the task execution was the key educational aspect:

"This [intervention] is very individual. It always depends on the mistake they make. Some do what we tell them and they do not get confused while doing their kitchen tasks and accept the critique." (P2)

Certain complex aspects of cooking required constant verification from the supervisors and fewer opportunities for independence. For these tasks, the supervisors often overstepped their role as supervisor to join into the cooking process directly. For example, the spice cupboard required careful instruction and often the supervisors would administer spices without any help:

"Managing spices is an interesting question: Who dispenses the spices? Our experience shows that adding spices is a fine-motor task requiring experience to not, for instance, over salt a meal. Spicing is mostly done by supervisors." (P1)

However, some tenants had stronger fine motor skills than others and performed spicing in the supervised session with direct instructor supervision.

This intervention was in part based on tenants' individual skill limitations, and was an integrated part of the supervision. Supervisors needed to bear in mind the specific tenants' perception of the cooking experience in each session, and be aware of stimuli that the tenants could not always process:

"I do not think that cognitively impaired people are able to determine when a meal is cooked or not." (P1)

Finally, supervisors recognized that more instructions could be provided to the tenants and they could possibly benefit from more attention to improve their long-term educational outcomes within the kitchens. However, the number of personnel available for communal cooking was limited:

"It is a communal kitchen. They have their own room, but in principle, they should be able to cook for them-

selves. The process of learning how to cook independently in one's own house should be learned here." (P1)

Practicalities

Our last theme addresses the practical concerns involved in the cooking activities. A core concern is maintaining the safety of the tenants, who may enter the facility with little knowledge about safe cooking procedures. As many kitchen tools are potentially dangerous and electrical appliances were in use, supervisors were especially careful to monitor tenants as they performed potentially dangerous actions, but had to make crucial tradeoffs between safety concerns and independence:

"Knives, blender, everything that can cause potential injuries is dangerous. We try to avoid every chance where injuries could happen. But this is not right since they will not learn how to cut or blend... however, they have to learn how to cut or blend [to cook independently]. Therefore, negative experiences are necessary to learn what causes injuries. But our primary goal is to avoid these injuries as much as we can." (P1)

Thus, the staff made risk assessments to determine if the use of particular skills outweighed their danger. Further, some supervisors mentioned that they prioritized the use of devices that offered a greater degree of safety, such as the microwave oven:

"The microwave offers comfort and security. Food is just put in and the microwave tells them when the food is ready." (P1)

Some tenants were aware of the safety risks of certain tools, and would monitor each other and repeatedly provide feedback when they observed safety violations.

Another facet of the cooking experience that we observed was making sure that the process was hygienic. Hygiene rules were imposed on the facilities by legal regulations, and needed to be followed and enforced strictly by the staff:

"We provide a hygienic plan. The housekeeping management organizes hygiene schooling. Furthermore, hygiene is taught to the tenants over time, for instance, how to wash hands, disinfect them, and how to wear gloves. Additionally, supervisors know the hygiene-related habits of tenants. This means that the individual hygiene is very diverse." (P1)

The medical condition of the tenants also affected the cooking experience. Distributing medicine was an integrated part of the communal cooking process, and the supervisors distributed pre-mixed dosages of pills in color-coded containers. The choice of the menu was also affected by health concerns:

"We serve salad as a side dish because of health reasons to ensure enough vitamins in meals. If we ask what they want to eat, they would prefer sausages, fried chicken, or fries all the time." (P1)

Lastly, participants were aware that cooking was connected with other activities, such as setting the table, and different tenants would perform these tasks in parallel with the cooking

tasks. While these activities required less help, supervisors still monitored if they were completed and coordinated:

"The tenants doing kitchen service needs to set up the table accordingly; including drinks and cutlery." (P1)

IMPLICATIONS FOR DESIGN

We present the lessons learned in the form of implications for design. These implications present an overview of the design space of assistive system for cooking in sheltered living facilities. The implications can be used by future designers to assure that possible solutions for cooking benefit the cognitively impaired users. These implications are derived from the themes presented above. Although these implications are derived for persons with cognitive deficiencies, we believe that these could be generalized to implement smart kitchens for elderly populations, who often begin to experience cognitive decline through the aging process [3, 10, 15], as well as assistance systems integrated into other household environments.

Support Clear Task Division

From our inquiries, we learned that tasks have to be intelligently distributed and communicated among tenants. The goal of the tasks was communicated verbally since most of the tenants were not able to read or write. During our studies, we found that continuous support was needed. Supervisors were reminding tenants from time to time about their current task and kept them motivated. Furthermore, the quality of their work was evaluated and criticized by both supervisors and other tenants when necessary, as we observed in the SUPERVISION theme. As a consequence, future smart kitchens should communicate recipes and tasks in a clear manner; *explicitly providing feedback on the component tasks that make up the cooking process*. Furthermore, attention and motivation should be fostered by highlighting the current task to be performed repeatedly. Division of labor should be explicitly supported, giving the supervisor freedom in orchestrating the cooking experience based on their awareness of tenants' diverse capabilities, and should help them maintain an overview of all the activities in the kitchen.

Embrace the Group Experience

Our analysis revealed that maintaining social ties between supervisors and cohabitants was an important factor on each tenant's route to greater independence. In the COMMUNITY theme, we observed how cooking represented an important social activity, where tenants worked together to achieve a communal goal. Managing social activities and minimizing opportunities for conflicts within the group was regarded as a key role for supervisors. Furthermore, some tenants were not motivated to cook, since it required extra effort and paying attention to additional constraints as shown in the PRACTICALITIES theme, but were more motivated by their role in the larger community of the kitchen. Our research suggests that adaptive motivating elements should be *integrated to maintain and augment the social experience of cooking together*. For example, showing visible achievement metrics or cheering cartoon figures as a token of appreciation for completing a

task may foster social interaction. Further, assistance systems should support conflict resolution by accounting for the tenants' unique abilities and personalities.

Prioritize High-Safety Instructions

Safety during cooking was the main concern for supervisors. As cognitively impaired persons perceive pain differently, the risk of severe injuries is higher than among neurotypical populations [9]. In the PRACTICALITIES and SUPERVISION themes, we observed how instruction always prioritized safety features for tasks that posed a possible danger. Consequently, smart kitchen systems for the cognitively disabled should *only feature displays in safe areas*, where the probability of getting injured is minimized. As dangerous tasks, such as operating the stove, cannot be fully avoided, the system should clearly communicate safety hazards to avoid severe injuries. As we observed, some of the cognitively impaired tenants had issues retaining focus; drifting in and out of the kitchen space during the completion of a single task. Future systems should *clearly show dangers that have a temporal aspect*, for instance, communicating that a hot plate cannot be touched until it has cooled down to a safe temperature.

Enable Customization for Different Abilities

In our work, we observed cognitively impaired users with a diverse set of abilities and impairments. In the PRACTICALITIES theme, we observed that some users were able to occupy themselves with dispensing spices, measuring water, or performing tasks that required fine motor skills; while these tasks were inaccessible to others. While supervisors strived to find an optimal division of the tasks, managing multiple parallel activities and the complex learning curves of multiple tenants was a very complex task as shown in the SUPERVISION theme. Future systems can not only aid in finding optimal ways to divide the tasks involved in preparing a meal but also *adjust the difficulty of the task to support the learning process* of a given tenant. It is important to note that the information provided should foster individual abilities, therefore the system should monitor the learning process and adaptively increase or decrease assistance. Furthermore, once tasks are complete, instant individualized rewards should be available to maintain management and support communication with the supervisor.

Provide Opportunities for Explicit Communication

The COMMUNITY theme showed how users often required confirmation from their peer group or superiors when performing cooking duties. Further, in the WORK ORGANIZATION and PRACTICALITIES themes, we observed how the logistics of food preparation and constant movement in the kitchen affected attention and communication between the supervisors and tenants. Consequently, we see opportunities for fostering reporting to supervisors and an increased awareness of when tasks are finished or in progress. Future assistance systems for kitchens for the cognitively impaired should *explicitly encourage users to communicate with the supervisor* and show the group when tasks are completed. This, however, needs to be done in ways that do not provide distractions that may affect cooking performance.

DISCUSSION

The considerations we present above focus on designing for assistance in kitchens within sheltered living facilities. In contrast, here we brainstorm future directions for assistive technologies that assist cognitively impaired cooks in unsupervised, independent, or group settings.

Accessible Assignment of Complex Tasks

One of the primary roles of the instructors in the kitchens was dividing tasks among the tenants, monitoring ongoing preparations, and coordinating their work to create a full meal. We see this coordination work as an important space where intelligent technologies could supplement or replace the trained instructors in the future, both to address the staffing shortages that limit the use of sheltered living facilities and to enable cognitively impaired individuals to train in these skills from their own homes or the homes of family members.

The instructors created long-term plans for cooking tasks which pushed tenants to continue building their cooking skills and to complete cooking tasks even when they were not intrinsically motivated to cook at that particular time. Intelligent systems which assign cooking tasks must balance these complex needs by generating tasks that are incrementally more difficult over time, and by sensing and responding to users' current level of ability and motivation in a given cooking session. These ability levels may change dramatically between sessions, especially among individuals with cognitive impairments caused by brain injury or aging, and an automated system must be able to flexibly adapt after observing a users' competencies or difficulties in the kitchen.

Intelligent systems may also be useful for home environments, where a cognitively impaired cook may wish to cook collaboratively with neurotypical family members. Family members of people with cognitive impairments can be inadvertent perpetuates of disability stigma against their cognitively impaired loved ones, viewing them as less capable and giving them simplistic tasks and responsibilities [19]. These systems could engage in task division between the family members by identifying tasks which are appropriately complex for both the cognitively impaired and neurotypical participants, reducing biases around cognitive impairment and allowing the cognitively impaired person to maintain their role within the family structure.

Examining Collaborative Accessibility

Prior work has found that norms in environments where disabled people are the majority (*e.g.*, the National Federation of the Blind's annual conference) differ from norms in environments where disabled people are the minority [20]. In the independent housing areas of the sheltered living facilities we studied, all members of the cooking process have cognitive impairments, raising critical questions about how technologies can be designed to facilitate collaborative work without impacting the disability-specific norms of the tenants.

In the supervised observations, tenants turned to the instructing caregiver to ask questions or get feedback. This reliance on the instructor may make it difficult for tenants to develop truly independent skills in a supervised setting. As a result, the

instructors gradually reduce their involvement until the tenants are able to demonstrate a level of independence that qualifies them for independent housing. However, the 'independent' housing is anything but independent – tenants are surrounded by other cognitively impaired residents who they can turn to for support or instruction. Designing for these *collaborative* domestic settings is rarely studied in accessibility literature or is looked at between disabled and able-bodied partners rather than among members of a single disabled community. Future study of cooking practices among individuals with cognitive impairments can contribute greatly to our understanding of the co-construction of accessibility.

Limitations and Future Work

We recognize the importance of including representative users in accessibility research, as argued by [41], and strove to accurately represent the cooking practices of the cognitively impaired tenants we observed. However, due to the level of cognitive impairment among the tenants, and the facility's desire to minimize researchers' direct intervention into the cooking process, we could not perform a typical contextual inquiry with the tenants. Instead, we combined our observations with interview data from the facility staff, who may have their own biases in their interpretations of the tenants' actions and interactions [19]. While other HCI work studying cognitively impaired users also relies on caregiver stakeholders as informants (e.g., [16]), we see this as a major limitation of our current work. As we continue this thread of research, we intend to develop new methods to facilitate working directly with cognitively impaired tenants, perhaps drawing from prior work which leverages participatory design methods [21].

Our contextual observations and evaluation were affected by other constraints. The study and data collection was conducted focusing on West European living standards. The sheltered living facility model is unique to this context. Compared to other locations, different living habits regarding cognitively impaired persons may be present. Additionally, both of our observations were conducted in different sections of the same sheltered living organization, whereas cooking procedures in other facilities may be executed differently.

As a subject for future work, we want to investigate how complex cooking instructions can be displayed in an effective way. Communication of complex or novel information can cause confusion, while simplified visualizations may neglect to foster cognitive abilities. Therefore, we will investigate which communication modalities, such as auditory and different visual representation, are feasible to achieve this. Furthermore, we want to evaluate the user acceptance of different display technologies, such as televisions, smartphones, or projectors, in kitchens by tenants. This requires a contextual inquiry with the tenants themselves to gain more insights about personal needs for smart kitchens within communal cooking activities. We plan to include a specialized therapist for the planned contextual inquiries. Ultimately, a smart kitchen system meeting the necessary requirements discussed in this paper will be deployed and tested regarding user acceptance, affordability, and efficiency.

CONCLUSION

In this paper, we investigated the design space of smart kitchens for cognitively impaired persons living in sheltered housing facilities. Within qualitative contextual inquiries, we obtained data by observing the target group during cooking. Furthermore, interviews were conducted to explore design gaps in-depth. By analyzing the interviews, we derived the four relevant themes WORK ORGANIZATION, COMMUNITY, SUPERVISION, and PRACTICALITIES, which emerge as important factors. We conclude with five design implications, which should be considered when designing smart kitchens for cognitively impaired persons: clear communication of tasks, fostering the group experience, prioritizing safety, providing rewards, and enabling contextual adaptivity.

ETHICS STATEMENT

The research presented in this paper underwent the ethical approval procedures required by the conducting institution. Ethical approval from the German Federal Ministry of Education and Research was obtained along with the consent of the sheltered living facility.

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